THE PRE-ILLINOIAN LAKE CLAYS OF THE CINCINNATI REGION[1, 2]

FRANK R. ETTENSOHN

Department of Geology, University of Cincinnati, Cincinnati, Ohio 45221[3]

ABSTRACT

Pre-Illinoian clays have been known in Ohio since 1903 when W. G. Tight described their occurrence in the abandoned Teays River valley in south-central Ohio. Not until 1919 were similar clays noted in the Cincinnati region. These early occurrences were described from the unglaciated portions of northern Kentucky just south of Cincinnati, and their significance was not made clear. Because the clays occurred beyond what was then considered the Illinoian glacial boundary, the clays were called pre-Illinoian.

In the 1960's, clays similar in composition and occurrence were found underlying till regarded as Kansan in age both on the uplands and in the Teays-age river valleys in southwestern Hamilton County, Ohio. The clays have now been found overlying Teays-age alluvial deposits at elevations ranging from 198 m (650 ft) in the Teays-age river valleys up to 262 m (860 ft) in the Teays-age upland tributary valleys. Deposition in marginal lakes arising from the ponding of northward flowing Teays-age drainage is the favored origin for these clays.

Most of the clays are laminated rhythmites consisting predominantly of clay-size and silt-size aggregates of clay minerals with traces of sand-size particles. The principal clay minerals are illite and mixed-layered clays with lesser amounts of chlorite and kaolinite. The clays are relatively impermeable so that ground water travels only along distinct access routes, initiating calcareous concretions along them.

INTRODUCTION

The pre-Illinoian clays of the Cincinnati region are deposits of laminated materials, consisting predominantly of clay-size and silt-size aggregates of clay minerals with traces of sand-size particles. These deposits were first mentioned by Miller (1919), but received little study until the 1960's, at which time a general construction boom created many additional exposures of the clays. In this study, both new and old occurrences were examined in order to achieve a complete description of the character, setting, and composition of the pre-Illinoian clays in the Cincinnati region.

The area studied comprised all portions of southwestern Ohio and adjacent parts of northern Kentucky where the clays were known to occur (fig. 1). The area included Hamilton County in extreme southwestern Ohio, the three adjacent counties in northern Kentucky—Boone, Kenton, and Campbell—and also a small portion of north-central Gallatin County, south of Boone County. The clays are generally underlain by alluvial deposits and in places are covered by till.

The paper is divided into three parts. The first describes the character of the clays, and the second briefly describes the underlying alluvial deposits. The third part is a discussion of the regional geologic history before and during clay deposition, based on the setting and distribution of the clays and alluvium, and on additional data derived from the literature. In connection with this last section, the preglacial topography is inferred and mapped (fig. 2) and the extent of ponding, providing sites for accumulation of the pre-Illinoian clays is estimated (fig. 3).

CHARACTER OF THE CLAYS

In the following sections, eight physical attributes, which best characterize the clays, are discussed. These are: thickness, color, bedding, attitude of bedding,

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[3]Present address: Department of Geology, University of Illinois, Urbana, Illinois 61801.

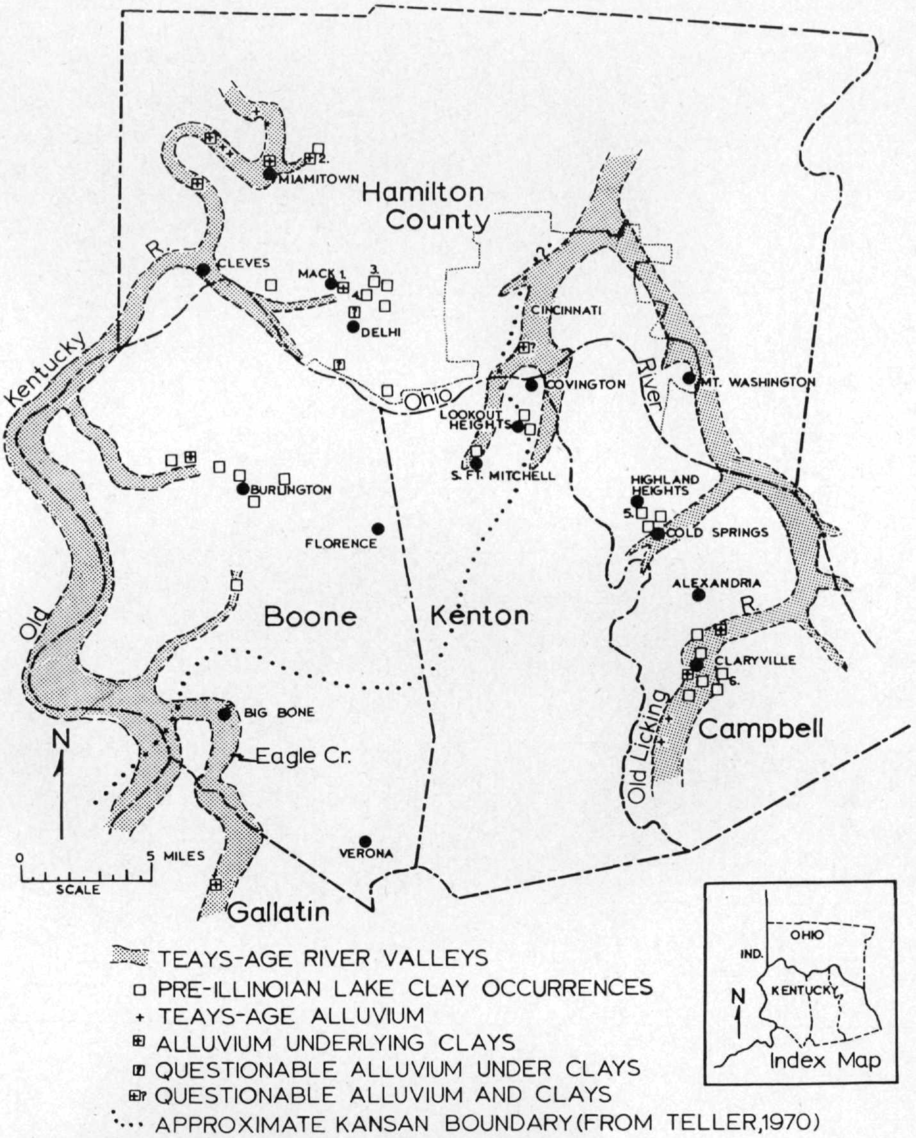

FIGURE 1. Map showing exposures of pre-Illinoian clays and Teays-age alluvium in southwestern Ohio and adjacent parts of northern Kentucky. The small numbers refer to specific localities mentioned in the text.

structure and jointing, clay mineralogy, other minerals, and paleontology. The final section deals with concretionary forms which commonly occur in the clays.

Thickness

Truly representative thicknesses for the clay deposits were difficult to determine because of erosional truncation and because of the configuration of the valleys in which they occurred. Clay thicknesses in measured clay sections range from 0.3 to 8.5 m (1–28 ft), but in most cases, the extent of erosion and the exact

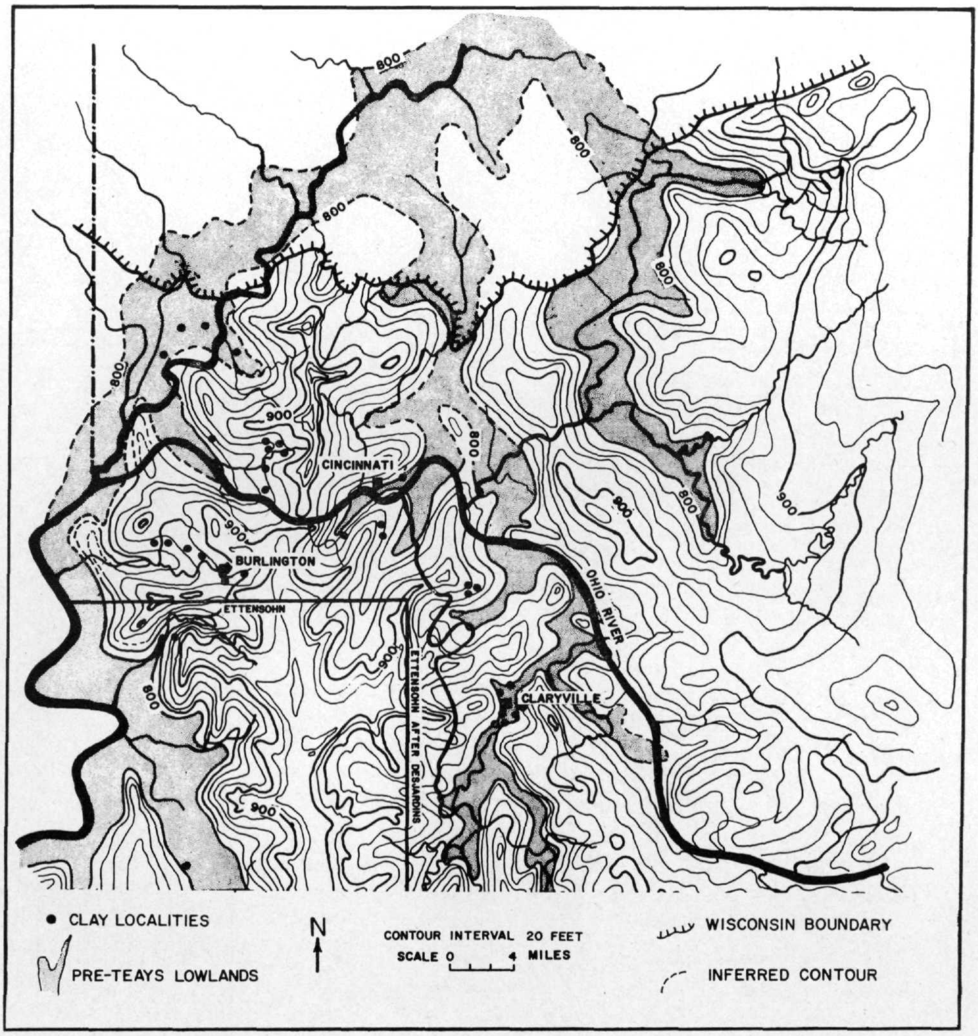

FIGURE 2. A restoration of topography on the Lexington erosion surface in the Cincinnati region. Note the prominent north-south divides.

valley configuration were not known. In the Teays-age Old Licking River Valley near Claryville, Kentucky, clays occur continuously between the elevations of 204 and 226 m (670–740 ft), but this outcrop occurs along the slip-off slope of a meander bend in the Teays-age river valley, so the apparent thickness is probably deceptive.

Color

The clays varied greatly in color, with hues grading subtly into each other. Earlier workers have described them as maroon, pinkish, red-brown, and brown. Using Munsell terminology, however, the clays show colors ranging from medium-dark gray (N4, moist) in their rare unoxidized state to dark reddish-brown (10R 3/4, moist) and yellowish-orange (10YR 6/6, moist) in their more commonly occurring states. The predominant color for these clays approximates a moderate brown (5YR 3.5/4, moist). Because the dark-gray clays, which are unoxidized and unleached, are found only as small pods near the center of the clay deposits, it appears that they have undergone little weathering, and that their color probably represents the original color of the unweathered clays.

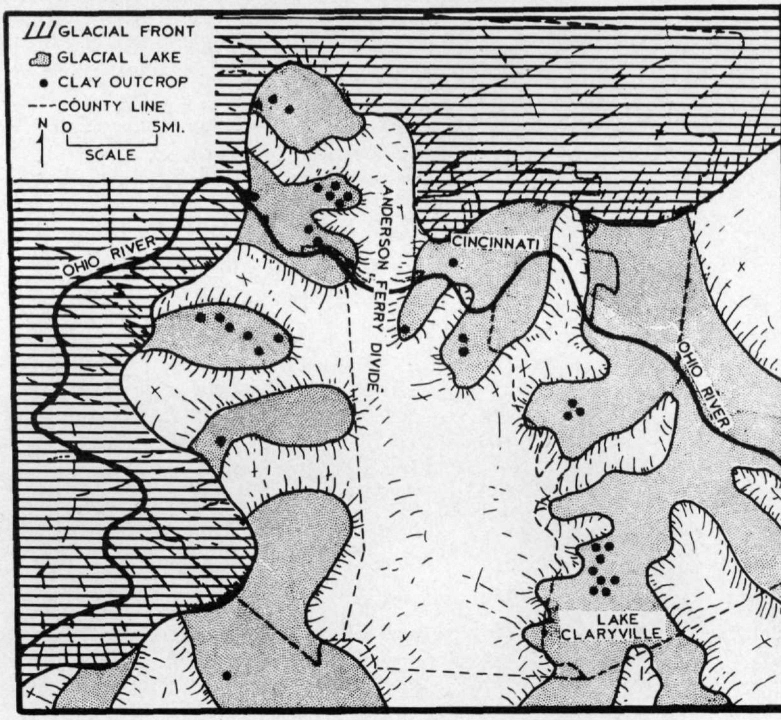

FIGURE 3. A possible interpretation of the extent of ponding by Kansan (?) ice in the Teays-age Old Kentucky and Old Licking River valleys.

Bedding

Bedding in the form of rhythmic laminations is characteristic of the clays. Clays from the Teays-age Old Kentucky River drainage (fig. 4) are finely laminated with occasional pale-blue (5B 8/2, moist) silty laminations. Clays from the Teays-age Old Licking River drainage, however, may be finely laminated, coarsely laminated, or massive, and pale-blue silty laminations are lacking. Even though some of the clays have a varve-like appearance, they are best described as rhythmites, since no annual depositional cycle has been established.

The finely laminated clays of the Old Kentucky River drainage consist of thin, light-colored, silty laminae alternating with thicker, dark-colored, less calcareous layers (fig. 4). Individual thicknesses of laminae range from 0.3 to 2.0 mm (0.01–0.08 in), and there is an average of eight lamination pairs per centimeter. When moist, these clays part along the light-colored laminae, but when dry, they break across the laminae with step-like fractures.

The pale-blue silty laminations occur as single layers in the clays of the Old Kentucky River drainage. The laminations are horizontally continuous in any one outcrop, and the clays part easily along them. These laminations, moreover, are highly calcareous, and X-ray diffraction study of them reveals their major components to be quartz, calcite, dolomite, and feldspar. The thickness of these laminations ranges from 0.3 to 2.3 mm (0.01–0.09 in), but both lamination thickness and frequency increase toward the top of the deposits. This was best demonstrated in the Werk Road outcrop, where pale-blue silty laminations were lacking in the basal portions of the deposit, but become common approximately 4 m (13 ft) above the base of the deposit, the distance between successive laminations ranging from 1 to 76 mm (0.04–3 in), with an average distance of 5 mm (0.2 in). Near the top of the deposit, approximately 8 m (26 ft) above the base, the pale-blue silty laminations became abundant, and successive laminations are closer than 5 mm (0.2 in) apart.

The coarser laminations of the Old Licking River drainage increase in thickness to 10 mm (0.4 in) and average one lamination pair per centimeter in outcrops near Highland Heights, Kentucky (fig. 1, no. 5 and fig. 5) and Claryville, Kentucky (fig. 1, no. 6). In the same area, more massive clays occur in beds over 30 cm (11 in) thick. These massive clays, some with indistinct laminations, break with a conchoidal fracture.

Attitude of Bedding

Dipping clay beds were observed in only two outcrops. At the Werk Road locality southeast of Mack, Ohio (fig. 1, no. 1), which is now a housing development, dips of 11 to 17 degrees were measured, and dips of approximately 20 to 30 degrees were measured in the clays from the outcrop at the junction of highways U.S. 52 and Interstate 74 (fig. 1, no. 2). In both instances, the dipping beds occurred along the bottom and sides of small valleys cut in bedrock. This suggests that the dips probably resulted from unequal deposition along the sides and bottoms of the valleys, which may later have been modified by slumping, differential compaction, or loading due to overriding ice.

Structure and Jointing

Structural features in the clays were found only in the Werk Road outcrop (fig. 1, no. 1). Here, concretions averaging 7 cm (2.8 in) in diameter and 8 cm (3.1 in) in height commonly had developed around many small normal and reverse

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EXPLANATION OF FIGURES 4–9

FIGURE 4. Fine rhythmic laminations from the Werk Road locality, south of Mack, Ohio (locality No. 1 in fig. 1).

FIGURE 5. Coarse rhythmic laminations from Highland Heights, Kentucky (locality No. 5 in fig. 1). Pen segment is 9 cm (3.5 in) long. (Photo by R. H. Durrell.)

FIGURE 6. Two concretions developed along fault lines in clays at the Werk Road locality (locality No. 1 in fig. 1). a) The left side of the concretion is displaced downward along a "larger" fault with a "smaller" fault on either side. b) Note the different dips on either side of the central "large" fault. Brecciation occurs along this fault, and there are a number of "smaller" inclined faults in the lower right portion of the concretion.

FIGURE 7. Linear concretions developed along randomly oriented joints in clays from the Werk Road locality (locality No. 1 in fig. 1). Shovel handle in left foreground is 51 cm (20 in) long.

FIGURE 8. Cylindrical concretion from the Werk Road locality (locality No. 1 in fig. 1). a) Top view showing the root penetration tube around which the concretion probably developed. b) Lateral view of the same concretion showing alternate clayey laminae and the thinner silty laminae (reentrants).

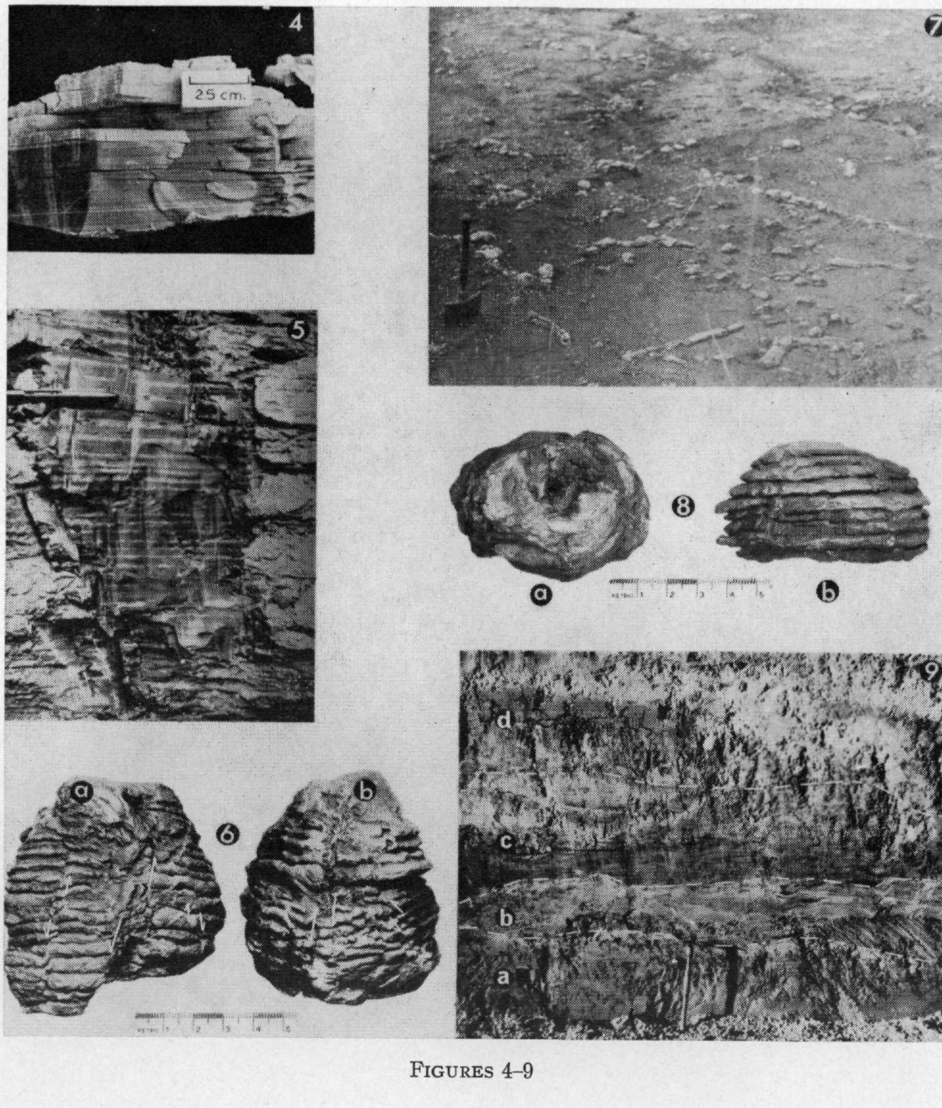
FIGURE 9. A stratigraphic sequence of glacial deposits showing increase in coarseness upward, from a foundation excavation on Blackberry Court at the Werk Road locality (locality No. 1 in fig. 1). Clays occur below the gravel foundation base at the bottom of the picture. a) fine, leached silts. b) coarser, leached silts. c) leached, oxidized sands grading upward into pea-size gravel. d) sandy Kansan (?) till. The two lowermost dashed contacts are erosional contacts. The shovel handle is 51 cm (20 in) long.

faults, preserving displaced and brecciated laminations (fig. 6). The lateral extent of these faults was only a few centimeters and the net displacement, a few millimeters. In another part of the outcrop, where the clay is covered by till, larger scale thrusting and folding have occurred at the till-clay contact, involving both the till and the clays. Possible causes for this deformation include slumping, loading, or stresses created in the unconsolidated clays by the overriding ice sheet.

Jointing in the clays was very common, and was often marked by the presence of linear-shaped concretions along the joints (fig. 7). The joints were randomly oriented, and their observable lengths varied from 5 cm to 6 m (2 in–20 ft). In some cases, a number of these joints intersected to form irregular polygons with perimeters of several meters.

Clay Mineralogy

Clay samples from each outcrop with calcareous clays were analyzed to obtain a semi-quantitative indication of the clay-mineral composition. Because non-



FIGURES 4–9

calcareous clays were always severely weathered, only calcareous clays were analyzed, as it was felt they would be more representative of the original clay mineralogy. Fifty-five oriented-clay slides representing 18 outcrops were analyzed using X-ray diffraction, and approximate percentages of clay minerals were calculated using an unpublished procedure developed at the Illinois State Geological Survey (H. Glass, personal communication, 1973).

Pipette analysis of the clays revealed an average textural composition of 82 percent clay, 18 percent silt, and less than 0.5 percent sand. The sand was primarily quartz, which was well sorted and subangular to rounded. In the less-than-two-micron size-fraction analyzed on the diffractometer, clay minerals were the predominant component; only rarely were peaks of quartz and calcite observed in this size fraction. Analysis of bulk samples gave similar results, except that the presence of calcite was more marked.

This predominance of clay minerals accounts for the compact nature of the clays, as well as their low porosity and permeability. Hence, the only routes of major water transfer through the clays are the thin pale-blue silty laminations, joints, and root-penetration tubes.

Diffractometer analysis revealed that, in most samples, illite was the dominant clay mineral, averaging 45 percent of the composition of all analyzed samples. Expandable-type clay minerals, such as illite-montmorillonite and chlorite-vermiculite, were the second most abundant clay minerals, averaging 38 percent. These two minerals probably occur principally as alterations of illite and chlorite (Willman, Glass, and Frye, 1966), as is evidenced, in the analyzed samples, by the inverse relationship between the percentage of illite and the percentage of expandable-type clay minerals. No such relationship for the alteration of chlorite was observed, probably due to the small amounts of chlorite present and the overwhelming abundance of the illite alteration-product, illite-montmorillonite, which obscured some of the essential chlorite-vermiculite peaks. Chlorite is the least stable of all the clay minerals present; alteration begins soon after deposition (Droste, 1956; Droste and Tharin, 1958). This rapid alteration of chlorite probably explains the low amounts of chlorite present in the clays. The average chlorite content for all the analyzed clays was 9 percent, although the chlorite content varied from only traces in the more weathered clays to 23 percent in the relatively unweathered clays from the Claryville area (fig. 1, no. 6). Kaolinite, however, was the most stable and consistent (in percentage present) of all the clay minerals present, even though it was least common, averaging only 7 percent of the clays analyzed.

Other Minerals

Bulk analysis of the clay samples with X-ray diffraction revealed that calcite was present in all calcareous samples, primarily in the silt-size fraction, and that dolomite was also present in some of the clays. Of the 29 localities sampled in this study, only 18 had calcareous clays. In the other 11 localities, the degree of weathering had been sufficient to leach all carbonate from the clays, clays which were typically highly oxidized with secondary accumulations of iron and manganese oxides. In the localities with calcareous clays, carbonate content varied from 7 to 27 percent, with an average of 16 percent, but this carbonate content was also apparently dependent in part on the degree of weathering, with the less weathered clays containing more carbonate. The depth of carbonate leaching, however, was quite variable; some deposits showed little leaching at all, while others were leached to depths ranging from 0.6 to 1.8 m (2–6 ft). These depths of carbonate leaching, however, are not truly representative of the full amount of possible weathering, because in nearly every case, there is evidence of erosional truncation.

The presence of certain soluble salts has also been noted from three clay exposures (Werk Road, Westbourne II, and Claryville; fig. 1, nos. 1, 3, 6). These salts precipitate out on the outcrop surface as the clays dry after each rain. The diffraction patterns of these efflorences were difficult to interpret, because of the impurity of the salts. A soluble form of gypsum, however, was definitely present, as well as probable alkali nitrates and sulphates.

Paleontology

Fossils are extremely rare in the clays. With the exception of a few wood fragments from the Werk Road outcrop and some rare pollen and spores, no fossils have been found in these deposits.

Concretions

Calcareous concretions (50–85 percent $CaCO_3$ by weight) are commonly found in most of the large pre-Illinoian clay deposits, and generally are not uncommon in glacial clays of any age (Kindle, 1923; Tarr, 1935). Most concretions in the Cincinnati-area deposits assume either a cylindrical form; a thin, flat, sheet-like form; or a linear-shaped form. The occurrence and shape of these concretions is governed by the location of ground-water access-routes through the otherwise impermeable clays, as well as by proximity to the surface (Ettensohn, 1969). The access routes insure water movement through the clays, while proximity to the surface insures that ground water can evaporate readily, leaving such concentrations of dissolved lime as to cause its precipitation as calcium carbonate. The common ground-water access-routes in these clays are root-penetration tubes, silt-rich laminations, jointing, and minor faulting.

The cylindrical concretions generally originated around root-penetration tubes and averaged 6.4 cm (2.5 in) in length and 7.6 cm (3.0 in) in diameter. All cylindrical concretions were perforated by a cylindrical tube (fig. 8), and polished sections through both the length and diameter of these concretions revealed concentric accretionary or growth zones surrounding the central tube. These concretions always occurred in the uppermost meter of the clay deposits, where root penetration is greatest, and were never found in clays overlain by other glacial deposits.

The thin, flat, sheet-like concretions took their shape from the pale blue silty laminations in which they occurred. The concretions often contained more than one lamination, and had thicknesses ranging from 2.5 to 5 mm (0.1–0.2 in). They were found only at or near the exposed surfaces of clay deposits.

The linear-shaped concretions originated along joints or minor faults, hence their distinctive form (fig. 7). These concretions ranged from 5 cm to 1.8 m (2–69 in) in length and averaged 7.6 cm in width. Polished sections showed that successive accretionary or growth zones paralleling the joint or fault were also present in these concretions.

In all these concretionary forms, a sharp contact always occurred between the surrounding clays and the concretion. The laminations in the clays, however, continued in an uninterrupted manner through concretions of all types.

ALLUVIUM

Underlying the clays, which occur in the abandoned valleys of the Teays-age drainage net, are stream deposits which occur in ancient stream valleys. Durrell (1961) called these deposits alluvial, and Swadley (1969), Luft (1970), and Gibbons (1971) called them fluvial deposits; the term alluvial will be used in this paper. There are, however, two distinct types of alluvium, based on occurrence and composition, a southerly derived alluvium, composed in part of chert, vein quartz, and coal, and a locally derived alluvium, composed predominantly of Ordovician debris.

Southerly Derived Alluvium

Southerly derived alluvium was found only in the two major through-going Teays-age river valleys considered in this study, those of the Old Kentucky River and of the Old Licking River. Such deposits occur underlying the clays in the Old Licking River valley around Claryville in Campbell County, Kentucky (Durrell, 1961; Luft, 1970; Gibbons, 1971) and at various locations in the Old Licking River valley in both Ohio and Kentucky (Hester, 1965; Swadley, 1969) (fig. 1). These deposits are composed of coarse, iron-stained sands with well-rounded pebbles of chert and vein quartz, locally cemented by limonite. Beds of sandy to silty clay and crossbedded clayey sands occasionally occur. Broken quartz geodes are commonly found in the alluvium from the Old Kentucky River valley (Swadley, 1969), while none occur in alluvium from the Old Licking River valley (Gibbons, 1971). Rounded coal pebbles, however, are found in alluvium from the Old Licking River valley (Hays, 1951), but are apparently lacking in alluvium from the Old Kentucky River valley (Teller, 1973). As the Cincinnati region is an area of Upper Ordovician shales and limestones, the presence of geodes, chert pebbles, vein-quartz pebbles, and coal pebbles indicates a source other than the local Ordovician strata. Mississippian and Pennsylvanian strata containing such materials crop out to the south in Kentucky, where they were readily accessible to the Teays-age rivers.

Locally Derived Alluvium

Locally derived alluvium is found underlying clays in valleys of small upland tributaries of the Old Kentucky and Old Licking Rivers. The alluvium is composed of local Upper Ordovician bedrock materials. The bulk of this material consists of pebble- and sand-size "ghost" particles of decomposed bedrock, as well as limestone slabs which are stained, have weathering rinds, and are coated with iron and manganese oxides. In some localities, these slabs are imbricated. Lenses of compact, crossbedded, silty to sandy clays are also commonly present.

Reworked Upper Ordovician fossils, especially brachiopod fragments, bryozoans, and crinoid columnals, are common in these alluvial deposits. Also present are small pelecypod and gastropod "steinkerns" 0.5 to 2.5 mm (0.02–0.1 in) in size (A. LaRocque, written communication, 1969). A few Pleistocene fossils were present, including wood fragments, pollen, spores, and a possible rodent tooth-fragment.

Another persistent feature of this buried alluvium is its deep weathering. The alluvium has been almost wholly leached of calcium carbonate and is mottled with iron- and manganese-oxide staining. The manganese oxide is also present as irregular blotches, dendrites, and small botryoidal pyrolusite crystals. These same oxides coat joint surfaces, and commonly form liesegangs along the joints. Gypsum also occurs locally in the alluvium as groups of small radiating acicular crystals. Where Upper Ordovician shales and limestones are visible beneath the alluvium, they are commonly oxidized to depths of 2 meters (6.5 ft).

The deep weathering of the alluvium may be explained by three different conditions, listed below, which can be viewed as acting together and or separately.

(1) The weathering may represent an *in situ* soil on the alluvium. However, there are no distinguishable soil horizons, and the alluvium appears to be weathered equally throughout its thickness.

(2) Some components of the alluvium may possibly have already been weathered before deposition, and such features as "ghost" particles, pyrolusite crystals, and liesegangs may have resulted from subsequent weathering.

(3) The porous alluvium, when sandwiched between the relatively impermeable underlying bedrock and overlying glacial clays, acts as a local aquifer. Solutions percolating through the alluvium may produce some of the observed weathering effects by leaching out some components and depositing others.

In some respects, the weathered deposits considered in these possible interpretations appear similar to zones which have been called possible paleosols (Goldthwait, 1959)—"leached, clay-enriched zones" (Gooding, *et al.*, 1959), and "Beta horizons" (Bartelli and Odell, 1960).

HISTORICAL INTERPRETATIONS

Based on the nature and distribution of the clay and alluvial deposits of the Cincinnati region, a Pleistocene geologic history of the area can be inferred. Prior to glaciation in the Cincinnati region, the area was characterized by a gently sloping erosional surface sometimes called the Lexington Peneplain (Fenneman, 1916, 1938; Desjardins, 1934). Relief in the area was generally no more than 46 m (150 ft), with the bottoms of large valleys at elevations of 244 m (800 ft) (fig. 10) and the divides at 274 to 293 m (900–960 ft) (Desjardins, 1934) (fig. 2). Desjardins (1934) pointed out that:

> The peneplain has generally been more largely preserved near the original divides than near the original valleys, since in spite of later drainage changes, modern streams tend to avoid old divides for the most part. Hence, the pattern of old divides is better preserved than the pattern of old streams. But in any area of ideal dendritic drainage pattern, there will occur a pattern of branching divides symmetrically disposed between the streams, and if the divides are preserved sufficiently to allow their pattern to be restored on a map, it should be possible to restore stream patterns with a fair reliability by interpolating between divides.

Using this principle, Desjardins (1934) restored the peneplain surface and the preglacial drainage pattern based on the then-existing 1:62,500 topographic maps. Figure 2 shows the writer's revision of Desjardin's restoration, incorporating updated 1:24,500 topographic maps.

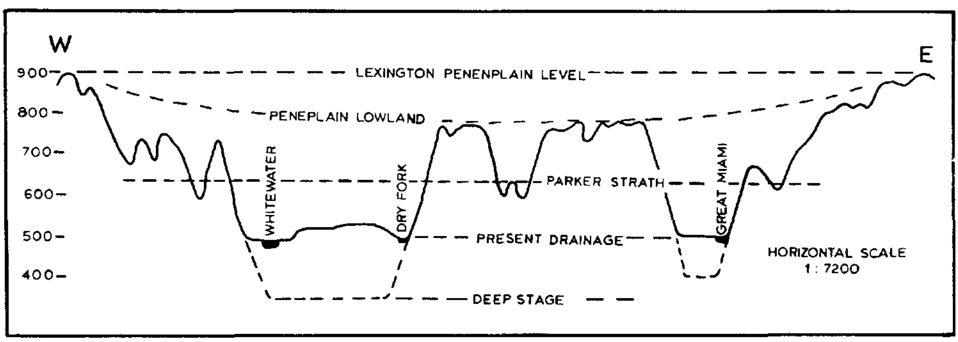


FIGURE 10. A cross-section of the Great Miami River valley north of Hooven, Ohio, displaying a pre-Teays valley at 224 m (800 ft) (commonly with clay fillings), Deep Stage drainage at approximately 107 m (350 ft), and present drainage at approximately 152 m (500 ft) (after Hester, 1965).

Base level was lowered, prior to the first glaciation of the region, so that streams originally flowing at 244 m (800 ft) became incised into the Lexington erosional surface down to elevations of approximately 198 m (650 ft) (fig. 10). This initiated the so-called Parker Stage of erosion and formed the Parker Strath at approximately 198 m, on which the southerly derived alluvium of the Teays-age drainage occurs. The causes for such a drop in base level are conjectural at this time. Possibilities include uplift, static rejuvenation, and stream diversion. It is also possible that a very early glacier, present only far to the north or west, might have effected this change. Both Coffee (1958, 1961) and Durrell (1961) have suggested that the pre-glacial Teays drainage flowed northward into the Great Lakes basins and was diverted westward by a Nebraskan glacial advance. Some evidence for such a glacial advance has been reported for eastern Ohio (Lessig, 1959a, 1959b) and such a diversion could have caused a lowering of base level. Teller (1973), however, discounts such a diversion. Nonetheless, these valleys were occupied by preglacial Teays drainage, drainage that most workers now agree was northward-flowing in the Cincinnati region (Teller, 1973).

When the first glaciation advanced southeasterly into the Cincinnati area (Teller, 1970, 1972), this northward-flowing drainage was blocked and ponded, producing the preglacial lakes in which the pre-Illinoian clays were deposited. These clays in the Cincinnati region occur at elevations ranging from 198 m (650 ft) in the major Teays-age river valleys to 262 m (860 ft) on the uplands. These clays occur most commonly at elevations of 198 to 213 m (650–700 ft) in what were the valley bottoms on the Parker Strath, and at elevations of 250 to 262 m (820–860 ft) on the ancient uplands. The upland deposits appear to represent clays deposited in small, ponded tributary valleys. Direct evidence for these valleys is difficult to detect unless the exposures are extensive enough to reveal cross-sections of the valleys. Valley cross-sections revealing the complete clay-alluvium fill are known from only three exposures (fig. 1, nos. 1, 2, 3), where the valleys have widths ranging from 15 to 152 m (50–500 ft).

A hypothetical drawing representing a possible configuration of this pre-Illinoian ponding is shown in Figure 3, constructed by imagining all lowlands containing clays in Figure 2 to be ponded to an elevation of 262 m (860 ft), the elevation of the highest clays found in the Old Kentucky and Old Licking River basins. Widespread ponding in the Old Kentucky River basin was never very likely, because elevations greater than 262 m (860 ft) were not present in the headwater regions of the Old Kentucky River. Indeed, in some southern segments of this basin, pre-Illinoian outwash directly overlies Teays-age alluvium (Kerr, 1950; Middendorf, 1951), suggesting that ponding may never have occurred. Teller (1973) has suggested that portions of the Old Kentucky River may have been captured through piracy by the nearby Old Ohio River flowing westward, thus explaining the lack of extensive clay deposits in this basin. In the headwaters of the Old Licking River basin, however, extensive occurrence of elevations, greater than 262 m (860 ft), support a widespread ponding throughout that basin.

During this first glaciation, the ice deposited a clayey till, informally called the Cincinnati Till by Teller (1970), on the uplands west of Cincinnati and in adjacent parts of northern Kentucky. The clays in this study always occur beneath this till or beyond (south of) it. At the Werk Road outcrop in Mack, Ohio (fig. 1, no. 1), a stratigraphic sequence showing an increase in coarseness upward above the clays marks the successively closer approach of the ice sheet. Pre-Illinoian clays in this outcrop (fig. 9) are overlain in ascending order by fine silts, coarse silts, sands grading into pea-size gravel, and then by the Cincinnati Till itself.

The age of the Cincinnati Till and the related pre-Illinoian clays is not certain. Because the till is leached to greater depths than is Illinoian till (Teller, 1972, 1973), and because the deposits lie beyond the Illinoian glacial boundary, they are often called simply pre-Illinoian. At present, however, they are commonly regarded as Kansan in age (Flint, *et al.*, 1959; Durrell, 1961; Teller, 1972), and, north of the Ohio River are mapped as "Kansan (?)" (Goldthwait, *et al.*, 1961), but others (Leighton and Ray, 1965; Ray, 1966; Swadley, 1971) have suggested a Nebraskan age for the till and therefore for the associated clays.

CONCLUSIONS

1. The Pre-Illinoian clays in the Cincinnati region are laminated rhythmites, consisting predominantly of clay-size and silt-size aggregates of clay minerals with minor amounts of sand-size quartz. Approximately 82 percent of the analyzed clay was clay-size material (almost wholly clay minerals), approxi-

mately 18 percent was silt-size material (predominantly clay minerals with some calcite), and less than 0.5 percent was sand-size quartz. The principal clay minerals were illite and mixed-layered clays, with lesser amounts of chlorite and kaolinite.

2. Clays found in the Teays-age Old Kentucky River drainage were always finely laminated and contained pale-blue silty laminations. Clays found in the Teays-age Old Licking River drainage were either finely laminated, coarsely laminated, or massive; pale-blue silty laminations were lacking.
3. The clays are commonly found at elevations of 198 to 213 m (650–700 ft) overlying a southerly derived alluvium in the abandoned, preglacial Teays-age river valleys, and at elevations of 250 to 262 m (820–860 ft) on the uplands. The upland deposits lie above a locally derived alluvium and apparently represent clays deposited in small tributary valleys.
4. Deposition in marginal lakes arising from the ponding of northward-flowing, preglacial Teays-age drainage is the favored interpretation for the origin of the clays. Ponding was widespread in the Old Licking River basin, but was localized in the Old Kentucky River basin.
5. The deposition of these clays is certainly linked with the first glacial advance into the region. However, the age of this advance is not certain. It is most commonly regarded as Kansan, but some have also suggested a Nebraskan age.

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